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A novel approach to falls classification in Parkinson's disease: Development of the Fall-Related Activity Classification (FRAC)

Annie Ross[1], Alison J Yarnall[1], Lynn Rochester[1], Sue Lord* [1]

[1]Institute of Neuroscience, Newcastle University Institute for Aging, Newcastle upon Tyne, UK

Correspondence to:
Sue Lord PhD
Institute of Neuroscience,
Newcastle University Institute for Aging,
Newcastle University
Newcastle upon Tyne
NE4 5PL
Email: sue.lord@ncl.ac.uk

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* Corresponding author.
Institute of Neuroscience, Newcastle University, Clinical Ageing Research Unit, Campus for Ageing and Vitality, Newcastle upon Tyne NE4 5PL, UK. Tel.: +44(0)191 2081291.

E-mail addresses: annie.ross@nuth.nhs.uk (A. Ross), alison.yarnall@newcastle.ac.uk (A. Yarnall), lynn.rochester@newcastle.ac.uk (L. Rochester), sue.lord@newcastle.ac.uk (S. Lord)

ABSTRACT

Background: Falls are a major problem for people with Parkinson's disease (PD). Despite years of focused research knowledge of falls aetiology is poor. This may be partly due to classification approaches which conventionally report fall frequency. This nosology is blunt, and does not take into account causality or the circumstances in which the fall occurred. For example, it is likely that people who fall from a postural transition are phenotypically different to those who fall during high level activities. Recent evidence supports the use of a novel falls classification based on fall related activity, however its clinimetric properties have not yet been tested.

Objective: This study describes further development of the Fall-Related Activity Classification (FRAC) and reports on its inter-rater reliability (IRR).

Method: Descriptors of the FRAC were refined through an iterative process with a multidisciplinary team. Three categories based on the activity preceding the fall were identified. PD fallers were categorised as: 1) advanced 2) combined or 3) transitional. Fifty-five fall scenarios were rated by 23 raters using a standardised process. Raters comprised 3 clinical subgroups: 1) physiotherapists, 2) physicians, 3) non-medical researchers. IRR analysis was performed using weighted kappa coefficients and included sub group analysis based on clinical speciality.

Results: Excellent agreement was reached for all clinicians, $\kappa = 0.807$ (95%CI 0.732-0.870). Clinical subgroups performed similarly well (range of $\kappa = 0.780 - 0.822$).

Conclusion: The FRAC can be reliably used to classify falls. This may discriminate between phenotypically different fallers and subsequently strengthen falls predictors in future studies.

INTRODUCTION

Falls are a major problem in Parkinson's disease (PD) with a recent systematic review demonstrating that 60% of people with PD fall at least once each year with 39% reporting recurrent falls [1]. Many studies have investigated risk factors for falls [2-5] yet our understanding of falls predictors remain limited. Falls are multifactorial with a complex pathophysiology [6] and solely reporting frequency of falls may not be sensitive enough to accurately identify risk factors. The most robust prediction of falls is two or more falls in the previous year [4], however there is also a clinical need to identify prodromal fallers in order to prevent the spiral of fear of falling and reduced physical activity with consequent functional decline [7].

Conventionally in falls research, falls frequency is used as the primary outcome without consideration of the circumstances in which the fall occurred. Understanding this is important because it is likely that people who fall whilst turning or standing up are phenotypically different to those who fall during higher level activities such as while walking [5]. Different risk factors may therefore underpin falls risk; a distinction that is lost when reporting frequency alone. Although falls frequency is sensitive to risk factors such as disease severity and recurrent fallers show different fall characteristics and clinical features to single fallers [8], this knowledge has limited clinical utility. Importantly, established (recurrent) falls are challenging to manage effectively, with recent evidence suggesting that

74 interventions to reduce falls are more effective for people with mild disease severity [9, 10].
75 Ideally, interventions will occur *prior* to the first fall occurring. This requires a more nuanced
76 approach to assessment and classification, and recognition of different faller phenotypes.
77
78 Earlier work has examined non-frequency based classifications. For example, fall related
79 activity has been described in relation to falls [5, 8, 11, 12] with walking identified as the
80 most common fall related activity [11, 12]. Location has also been shown to influence risk
81 factors [13, 14] with indoor falls associated with disability, poor health and inactivity, in
82 contrast to outdoor falls which are associated with an active lifestyle and average or better
83 than average health [13]. Another approach is to describe the mechanism of the fall [15-18]
84 using terms such as 'extrinsic' which classifies the circumstance surrounding the fall and
85 may include environmental descriptors (e.g. obstacle, hazards) or the specific fall related
86 activity. Other descriptors include biomechanical perturbation that preceded the fall [19,
87 20] for example a 'base of support' fall (a slip or trip), or a 'centre of mass' fall (bending or
88 reaching). Very few studies have categorised falls based on fall related activity such as: a)
89 transferring, stooping, bending, or standing still; (b) walking; (c) turning around or reaching;
90 (d) going up or down stairs, steps or curbs; and (e) "high risk" activities like running or
91 standing on a chair [12, 21]. However, apart from one classification which reported a
92 reliability of $\kappa = 0.828$ [17], none of these classifications have been formally scripted, tested
93 or adopted.
94
95 We considered the advantages and disadvantages of previous falls classifications, and also
96 conducted some preliminary research that resulted in our decision to adopt a novel
97 approach. For the preliminary research, we explored the relationship between ambulatory

activity and falls in people with PD and compared this association for falls frequency and falls context. In order to do this, we first developed a classification based on fall related activity. At 12 months 36.9% of the cohort had fallen. Total time spent walking was significantly lower for transitional fallers compared with non-fallers and they also had significantly increased disease severity. There were no significant relationships when fallers were categorized by frequency. This demonstrates greater discrimination for fallers versus non-fallers when the falls context classification was used [5]. However, reliability testing of the classification was limited to an informal assessment whereby four raters classified 20 fall scenarios from which a Fleiss' kappa coefficient $\kappa = 0.643$ (95% CI 0.513-0.686 was obtained. The aim of this study was therefore to formally examine the inter-rater reliability of this falls context classification, which we named the Fall-Related Activity Classification (FRAC) [5]. We also examined reliability results for raters clustered by clinical and falls expertise because we were interested in its generalisability.

METHODS

Description of Fall-Related Activity Classification (FRAC)

The original definitions and descriptors of the FRAC [5] were reworked and the original title, "ambulatory" was renamed "combined". Three categories are described based on a continuum of everyday activities (see Table 1 and Figure 1).

Reliability study fall scenarios

The fall scenarios for this reliability study were taken from the first 12 months of falls diaries from the ICICLE-Gait study falls database.

This is a collaborative study with ICICLE-PD, an incident cohort study (Incidence of Cognitive Impairment in Cohorts with Longitudinal Evaluation - Parkinson's disease); full description of this cohort is available elsewhere [22]. Briefly, the authors aimed to recruit all cases of incident idiopathic PD from secondary care services in Newcastle-upon-Tyne and Gateshead between June 2009 and December 2011. ICICLE-GAIT recruited a subset of the cohort at the same time point. Primary care (general practitioners) and secondary care (neurologists, geriatricians and PD specialist nurses) services were invited to notify the investigators of potential participants. Participants had their PD diagnosis confirmed by a consultant neurologist specialising in neurodegenerative diseases according to the UK Brain Bank Criteria [23]. Exclusion criteria included a diagnosis of Parkinsonism prior to study onset and non-idiopathic forms of the disease, such as drug-induced and vascular Parkinsonism and the atypical Parkinsonism syndromes including supranuclear palsy, multiple system atrophy or cortico-basal degeneration. This was to ensure that only cases of incident idiopathic PD were included. Participants were also excluded if they had evidence of a significant memory impairment or dementia, as evidenced by a Mini Mental State Examination (MMSE) score <24 or did not have sufficient knowledge of the English language in order to co-operate with testing. The study was approved by the Newcastle and North Tyneside Research Ethics Committee and all participants gave informed consent.

Throughout the study period participants were asked to record any falls that occurred in the past month on a standardised prompt sheet, including the date and time of each fall as well as location, preceding activity, perceived cause, position in which they landed and mode of recovery in a structured open-ended statement format. All reported falls were followed-up with a telephone call from a Senior Research Physiotherapist (DM) to verify information and

144 rectify any missing data. Fifty five falls scenarios were randomly selected from the first 12
145 months of recorded falls.
146
147 *Procedure*
148 A convenience sample of 25 raters from gerontology and neurology clinical and research
149 backgrounds within the local NHS Trust agreed to participate in the study. Standardisation
150 of the rating process was established to prevent bias. Raters were instructed to read
151 through the definitions and examples, familiarise themselves with the FRAC and then
152 independently categorise 55 scenarios in to one of three categories (see Table 1). No
153 formal training was provided. Raters were blinded to any information other than the
154 necessary details regarding the fall related activity needed to classify. Raters were asked 4
155 questions about their clinical background in order to answer the secondary research
156 question. An "expert in falls" was defined as those who work regularly/have worked
157 regularly in the past in falls clinics, or those who routinely assess and treat older patients at
158 risk of falls or following a fall in their clinical practice [24].
159
160 *Statistical analysis*
161 In order to minimise bias this study incorporated a fully crossed design, meaning that all falls
162 scenarios were rated by all raters. Light's [25] kappa was used to assess IRR because there
163 were more than 3 raters [26]. Squared weighting of errors was used to give partial credit for
164 judgements that disagree but are close**.** The "psy" package of R statistics v3.1.0 software
165 was used to calculate the kappa values and 95% confidence intervals were calculated using
166 the "boot" package.

RESULTS

Sample characteristics of raters

The final number of raters was 23. Eleven raters were physiotherapists, seven were physicians and five were non-medical researchers (bioengineer, bio mechanist, engineer, researcher and research technician). The mean number of years of experience working specifically with people with PD was 3.99 (range 0- >15 years), 16 raters had regular experience with fallers and six raters were deemed to be “falls experts”.

Distribution of types of falls rated

With respect to the most frequently chosen response across the 23 raters, 16 falls were classified as transitional, 27 were classified as combined and 12 were classified as advanced. Some more complex falls scenarios resulted in poor agreement (see Table 2).

Statistical estimates of inter-rater reliability with regards to rater population

Subgroups of clinicians performed similarly with all values indicating substantial agreement [27] and there was no statistically significant difference between the groups (see Table 3).

Statistical estimates of inter-rater reliability

Kappa was computed for each coder pair then averaged to provide a single index of IRR [25]. Excellent agreement was reached $\kappa = 0.807$ (95%CI 0.732-0.870) (see Table 3).

DISCUSSION

This study reports excellent inter-rater reliability for the FRAC suggesting it is a robust classification to identify falls. Importantly, reliability was upheld for all raters including non-medical clinicians and raters with fewer years of experience in falls management. Further work is required to validate the classification and more extensively test its clinimetric properties. Although the FRAC was developed for people with PD its application is likely to be broader. A fall is a generic event, and there is no reason why this classification should be limited to rating by a specific discipline. Future research will examine the utility and clinimetric properties of the FRAC for other populations including older adults, and investigate acceptability and utility.

Comparison with earlier reliability studies is limited, however results are in line with the only other falls classification to report reliability [17]. In this study two reviewers classified falls from a sample of community-dwelling adults into one of four categories and demonstrated k = 0.828. The taxonomy was extensive with four major categories each encompassing three levels: extrinsic (including falls, slips, trips); intrinsic (including mobility or balance disorders); falls from a non-bipedal stance (such as falls from bed/chair); and unclassifiable falls. This classification is limited in its clinical applicability and has not been widely adopted. In addition, only two raters classified falls using this taxonomy and both were geriatric nurses. It has been suggested that studies that include ratings from a single professional group suffer the risk that professional assumptions underlie the ratings, which may artificially inflate the reliability of the instrument [28]. In contrast, 23 raters from a variety of professional backgrounds validated the FRAC.

The FRAC is relatively simple with only three categories to select from and includes concise descriptors and a written guide to assist with classification. Also, no formal training is required to use it reliably, which demonstrates generalisabilty. The key limitation we noted was that some of the more complex falls scenarios resulted in poorer agreement because it was challenging to interpret the level of complexity of the activity and ensuing fall. Familiarity with the classification is likely to improve this. In addition the classification was unable to consider medication state or the role of freezing and festination in falls.

We advocate clinical and research use of the FRAC. A clinical understanding of pre-fall activity may help identify more specific and individualised fall prevention strategies. For example, identification of an individual who falls almost exclusively during postural transitions may mean therapy can be targeted towards function-based strengthening and basic balance training. By contrast, if falls are categorised as combined, then it is possible the individual may benefit from gait re-education, higher balance training, dual task training or cueing strategies to ameliorate the gait dysfunction which is possibly a contributing factor.

In addition, the FRAC may be used to provide a formal approach to fall classification which can be charted over time, but also, most importantly for early identification of falls with the intention of preventing the slide from an incidental 'high level' (advanced) fall to clinically significant and concerning 'postural transition' (transitional) fall. This common clinical assumption; that a high level fall may be a precursor to future lower level transitional falls, needs to be tested, and the FRAC is a more appropriate means to investigate this theory than classification by incidence.

Results from this study confirm the view that fallers vary phenotypically which is not evident when using falls frequency as a classification. Although recurrent falls indicate greater discrimination for pathology when compared to single falls [8], frequency as an outcome alone is limiting. Mactier [5] found a significant association between ambulatory activity and disease severity in incident PD was demonstrated when falls were categorised using the FRAC, whereas the conventional classification, frequency, did not yield these findings [5]. This lends weight to the notion that falls (and fallers) are not homogeneous. Inspection of the falls diaries revealed that participants were involved in a broad spectrum of physical activities (not reported here) which ranged from climbing down a moss covered peat bog before crossing a stream to simply getting out of bed. On the whole, transitional fallers were depicted as being frail and more advanced in disease severity versus advanced fallers who were portrayed as being more impulsive or lacking in insight. This has wider implications, and highlights the need for future work to understand the different risk factors conferred by grouping fallers and a potentially different approach to fall management strategies. Nevertheless, falls researchers and clinicians almost exclusively measure falls by frequency. This consistent approach enables between-study comparison and data consilience, but comes at a cost of reducing meaningful interpretation. This ultimately limits the advancement of falls research.

Strengths of this study include the design and methodology. Standardisation of the rating process prevented bias. Use of 23 raters is uncommon in reliability studies and the variety of professional backgrounds was an advantage. Limitations are that we did not measure test-retest reliability or examine the accuracy of the patient's description of falls. It could be of

interest to correlate this classification with not only information gathered from more objective measures such as accelerometers, but other classifications such as the postural stability measures of the UPDRS [29]; all of which could be the focus of future work.

CONCLUSIONS

The FRAC can be reliably used to classify Parkinson's disease fallers. Classifying falls in this way may discriminate between phenotypically different fallers which may increase the likelihood of detecting, and subsequently strengthen risk factors for falls. Additionally, the differences in fall types and outcomes may have implications for, and be used to guide fall prevention strategies.

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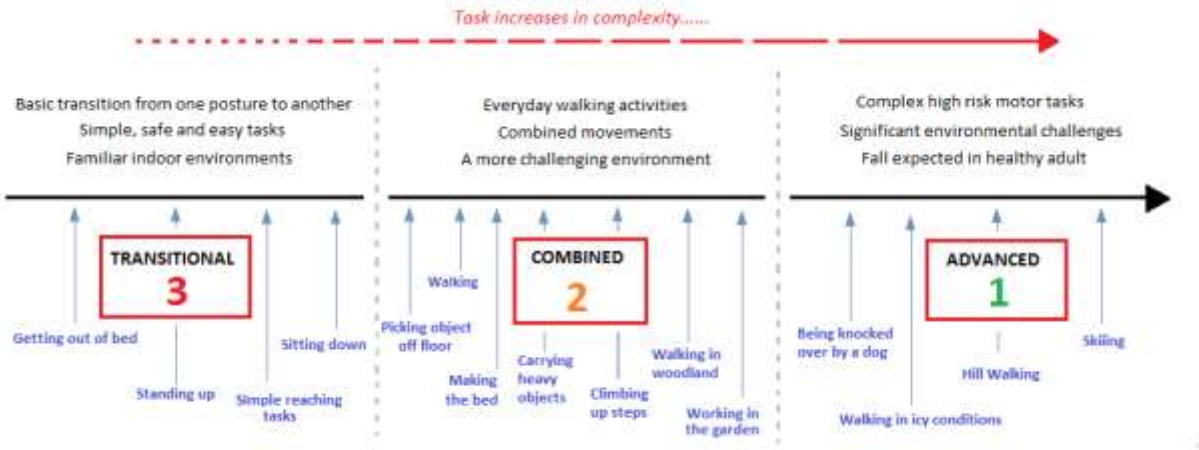

Figure 1: Falls Classification Continuum

Table 1: Fall-Related Activity Classification (FRAC) category descriptors

1. Advanced	2. Combined	3. Transitional
Involves a complex, high risk motor activity	Involves everyday walking activities including stair climbing or combined movements	Involves a basic transition from one posture to another
There is a significant environmental challenge that would explain the fall Unfamiliar indoor/outdoor environment	Combined movements include moving from one position to another in a more challenging environment	Simple, safe and easy tasks
e.g. Skiing, hill walking, slipping on ice	e.g. working in the garden, turning whilst walking, carrying heavy objects	e.g. rising from a chair, sitting on a sofa
The fall is expected in an age-matched non-PD person	The fall is not expected in age-matched non-PD person; it is a result of underlying physiological deficits	The fall is not expected in age-matched non-PD person

Table 2: Scenarios resulting in poor inter-rater reliability

Contentious falls scenarios			**% agreement**			**Potential causes of disagreement based on category descriptors *(in italic)***		
Where were you?	**What were you doing?**	**What do you think caused the fall?**	**1**	**2**	**3**	**Category 1**	**Category 2**	**Category 3**
Walking the dog in the woods at the park	Trying to walk and manage lead/ bag and walking stick	Tripped over a tree root while not paying attention to what I was doing. Ground was muddy + slippy after the thaw	**57**	43	0	**The woods at the park are an *unfamiliar environment.*** **Managing the lead/bag, tripping over tree root, slippy mud are all *significant environmental challenges that would explain the fall***	Walking the dog is a s*imple everyday walking activity*. You would *not expect the fall in age-matched non-PD person*	
In the back lane	Mounting bike	Lost balance	**39**	61	0	**Mounting a bike is *a complex, high risk motor activity***	Mounting a bike *is a combined movement, including moving from one position to another* The fall is *not expected in age-matched non-PD person*	
Fall on way to bed	I turned badly - overbalanced	Balance is very poor at times	0	**57**	43		**Walking to bed is an *everyday walking activity***	Walking to bed is a *simple, safe and easy task* It involves a *basic transition from one posture to another*
Kitchen	Trying to turn around to go out of the kitchen	Loss of balance	0	**61**	39		**Trying to turn around to go out of the kitchen is an *everyday walking activity***	Walking in the kitchen is a *simple, safe and easy task* It involves a *basic transition from one posture to another*
In kitchen	Open fridge door	Tripping over dog	22	**52**	26	Tripping over the dog is a *significant environmental challenge that would explain the fall*	**Opening the fridge door in the kitchen is an *everyday walking activity and a combined movement***	Opening fridge door is a *simple, safe and easy task*

Gold standard in bold (classified by AR)

Table 3: Kappa values

Clinical Subgroup	N	Light's Kappa ($CI_{2.5}$, $CI_{97.5}$)
All	23	.807 (.732, .870)
Physiotherapists	11	.822 (.750, .885)
Physicians	7	.821 (.747, .880)
Researchers	5	.780 (.697, .863)
Clinicians (physios & medics)	18	.815 (.744, .872)
Regular contact with fallers	16	.816 (.739, .878)
Falls experts	6	.810 (.697, .882)